

The Challenges for Organic & Glass core Substrates As Advanced Packaging RDL Approaches 2 μm L/S And Beyond

MAY 3rd, 2024

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Onto Innovation Snapshot

High tech capital equipment company specializing in optical process solutions for semiconductor and related markets

-  **FOUNDED 2019**
-  **1,500 EMPLOYEES**
-  **>9,000 ACTIVE METROLOGY & INSPECTION TOOLS INSTALLED**
-  **>80 Fabs FAB-WIDE YIELD/DEFECT SOFTWARE INSTALLED**
-  **\$816M 2023 REVENUE**

















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Onto Innovation's Main Products

 Panel level packaging solutions

METROLOGY						
INSPECTION						
LITHOGRAPHY						

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Onto Connected Panel Solution Accelerates New Product Ramp

Onto Connected Panel Solution

- Meets current and next generation adv IC substrate development requirements
- Accelerates time to solution in yield optimization
- Facilitates collaboration across adv IC substrate ecosystem

Value to Our Customers

- Increases manufacturing productivity
- Reduces overall investments to reach yield entitlement
- Enables shorter time for new product introduction
- Accelerates technology development



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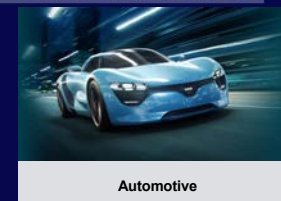
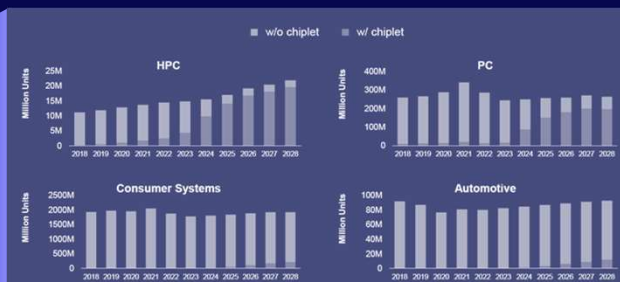
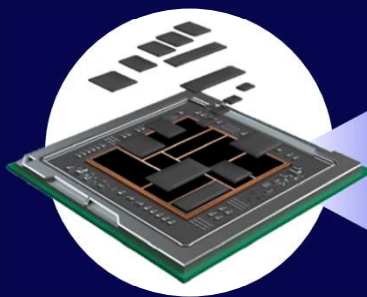


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Increasing Chiplet Adoption Across Different High Performance Applications

The Advanced IC Substrate is One of the Key Components for Integration

Source: Yole 2023

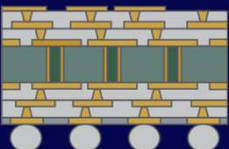


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Migration from Organic Substrates (CCL) to Glass Core



Organic Core Substrate

Is 2 μm I/s possible?

> 2027 ?

L/S 8/8 μm

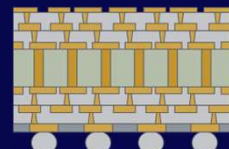
2024

5/5 μm

2025

2/2 μm

> 2027 ?



Glass Core Substrate

Processes requirements:

L/S	2/2 μm	1.5/1.5 μm	1/1 μm
Via CD	7 μm	5 μm	3 μm → 2 μm
Via Patterning	Hard Mask/PID	Hard Mask/PID	PID
RDL Patterning	Liquid PR	Hard Mask → PID	PID
Overlay	≤ 0.7 μm	≤ 0.5 μm	≤ 0.3 μm

L/S 2/2 μm


2025

1.5/1.5 μm

2028

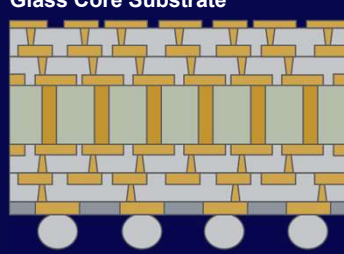
1/1 μm

2030+



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Glass Core 2 μm I/s and Beyond Challenges



Glass Core Substrate

Challenges	
Substrate Core	Thin glass panel handling TGV CDU (top, bottom, waist) and defectivity (cracks, residue) TGV plating uniformity Cavity for embedded dies
Hard Mask and PID for Patterning	Hard Mask - Material selection and selectivity to ABF PID - Material selection and reliability
Cu Seed Deposition	Adhesion, surface roughness and thickness control
Cu Via/Trace Plating	Plated copper roughness, Cu seed removal
Embedded Components	Embedded die shift

2/2 μm


2025

1.5/1.5 μm

2028

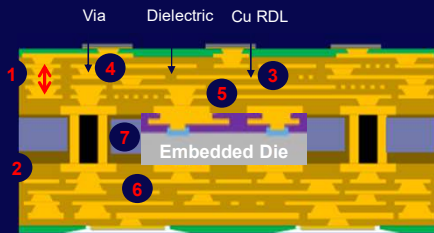
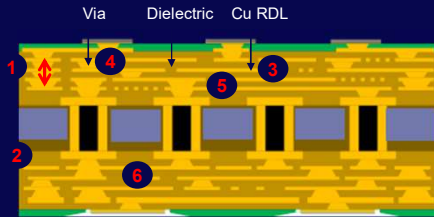
1/1 μm

2030+



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Organic Substrate (CCL) 2 μm I/s Challenges



Challenges

1. Overlay – Via to RDL Pad
2. Dielectric Lamination Uniformity and Defectivity Control
3. RDL 2D/3D Metrology and Defectivity Control
4. Via CD and Defectivity Control
5. Seed Layer Deposition Thickness Control
6. Via/RDL Plating Uniformity and Defectivity
7. Embedded Die Placement

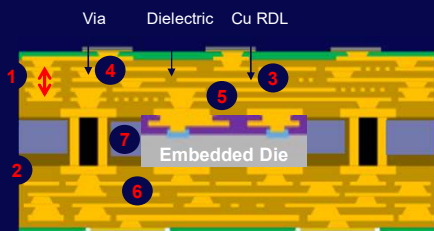
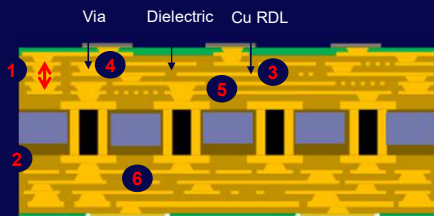
To reach 2 μm I/s:

- Production Overlay, RDL to Via ($12\ \mu\text{m} \rightarrow < 2\ \mu\text{m}$)
- Build up film, Via CD ($30\ \mu\text{m} \rightarrow < 10\ \mu\text{m}$),
- Process ramp must have acceptable yield

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Organic Substrate (CCL) 2 μm I/s Challenges



Challenges

1. **Overlay – Via to RDL Pad**
2. Dielectric Lamination Uniformity and Defectivity Control
3. RDL 2D/3D Metrology and Defectivity Control
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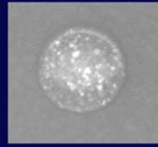
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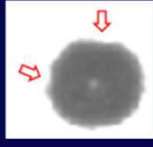
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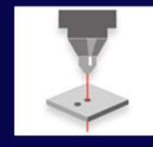
Challenge #1: Alignment Target Errors Induce Overlay instability



Poor Contrast of Alignment Mark



Poor Shape of Alignment Mark



Laser Driller Position Error

Alignment Solution Error



Overlay Error

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Challenge #2: Panel Distortion

JetStep® X500

- During panel processing, the continuous thermal cycling distorts the panel, which requires a lithography system to provide an alignment solution that delivers overlay performance that meets specification.

Solution: The JetStep X500 system utilizes a reticle chuck with 6 degrees of freedom, stage grid, and adjustable projection lens elements, to automatically provide an alignment solution that ensures high package yield.



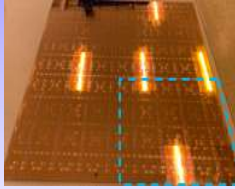
COPPER CLAD LAMINATE (CCL)
ORGANIC SUBSTRATE

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12

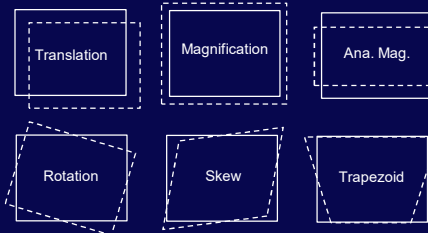
Distortion Components and Error Terms

Quadrant Scale Distortion Coefficients

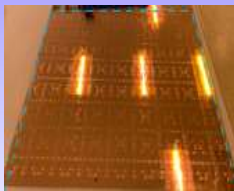


Term	Value
X Tran	-1.76E-03
Y Tran	5.97E-04
Mag	-3.06E-06
Ana Mag	-3.06E-06
Rotation	1.20E-05
Skew	1.20E-05
X Trap	1.67E-07
Y Trap	-6.28E-08

Quadrant Scale Distortion Component

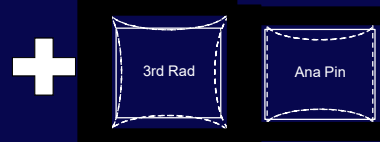


Panel Scale Distortion Coefficients



Term	Value
3rd Rad	2.75E-10
Ana	-2.81E-10

Panel Scale Distortion Component



Distortion Coefficient : Used in the equations that describe each term fit.

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Correction Method Discussion

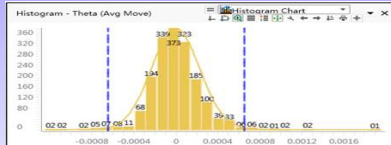
Non-Linear Error In Panel



Non-Linear Error Across Panel



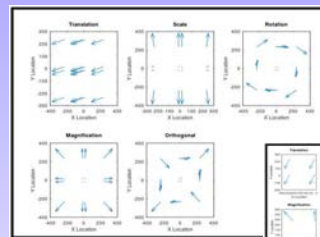
Zone Scale Error



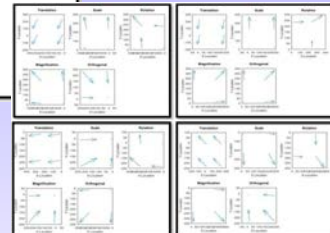
Large Range Rotation Error in Panel

Global Correction vs Zone Correction

Global Correction Terms



Zone Correction Terms



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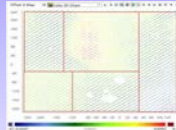
14

Correction Method Discussion

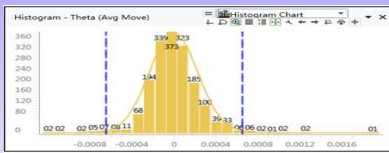
Non-Linear Error In Panel



Non-Linear Error Across Panel



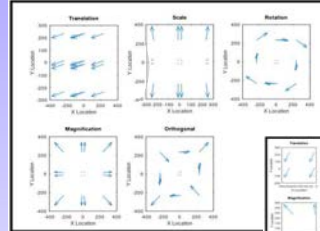
Zone Scale Error



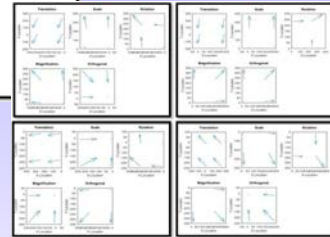
Large Range Rotation Error in Panel

Global Translation Toward Bottom-Left

Global Correction Terms



Zone Correction Terms



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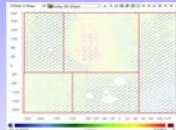
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Correction Method Discussion

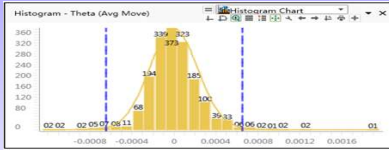
Non-Linear Error In Panel



Non-Linear Error Across Panel



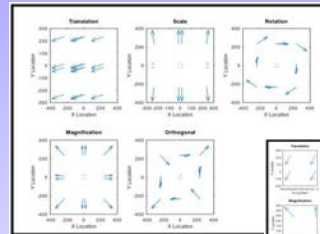
Zone Scale Error



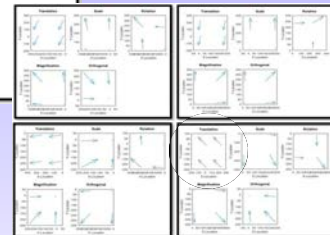
Large Range Rotation Error in Panel

Bottom-Right Zone Translation Toward Top-Left

Global Correction Terms



Zone Correction Terms



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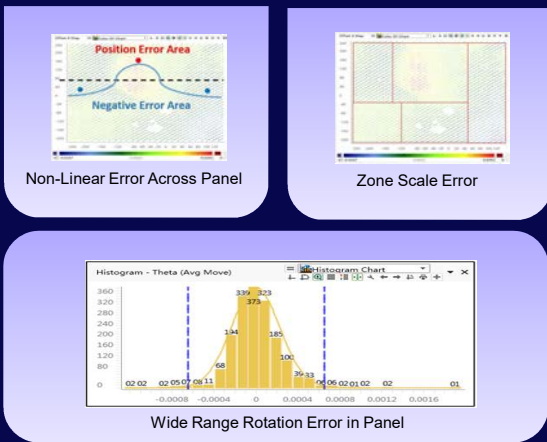
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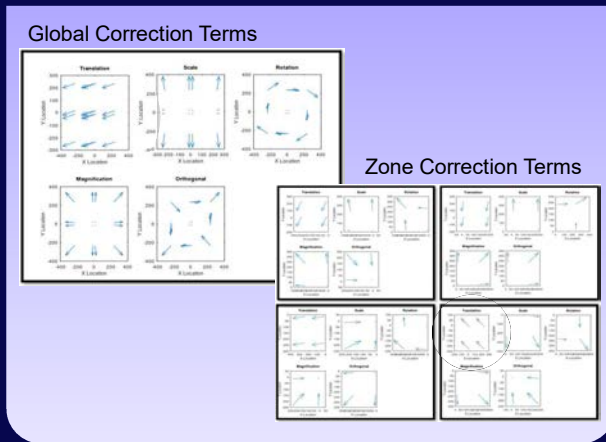
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Correction Method Discussion

Non-Linear Error In Panel



Global Correction Cannot Fully Correct The Error



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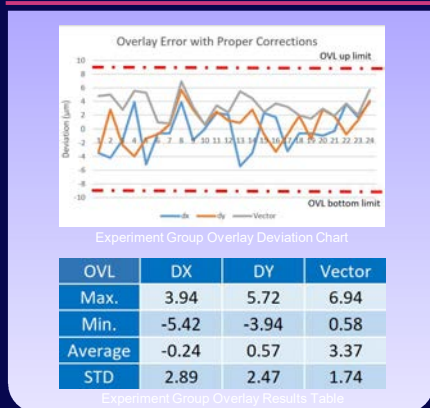
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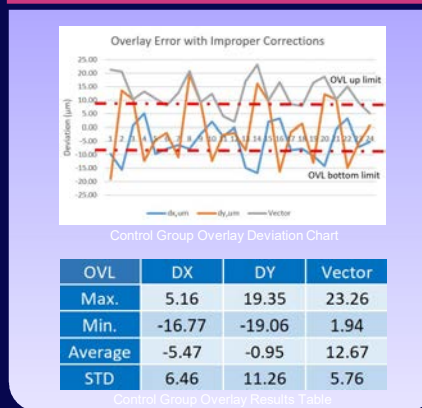
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Demonstration Review And Results

Experiment Group : Overlay Results with Proper Corrections



Control Group : Overlay Results with Improper Corrections



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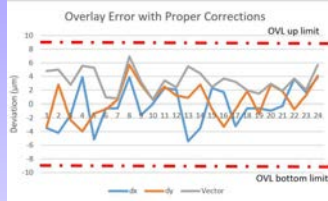
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Demonstration Review And Results

Experiment Group : Overlay Results with Proper Corrections

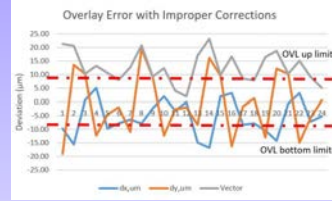


Experiment Group Overlay Deviation Chart

OVL	DX	DY	Vector
Max.	3.94	5.72	6.94
Min.	-5.42	-3.94	0.58
Average	-0.24	0.57	3.37
STD	2.89	2.47	1.74

Experiment Group Overlay Results Table

Control Group : Overlay Results with Improper Corrections



Control Group Overlay Deviation Chart

OVL	DX	DY	Vector
Max.	5.16	19.35	23.26
Min.	-16.77	-19.06	1.94
Average	-5.47	-0.95	12.67
STD	6.46	11.26	5.76

Control Group Overlay Results Table

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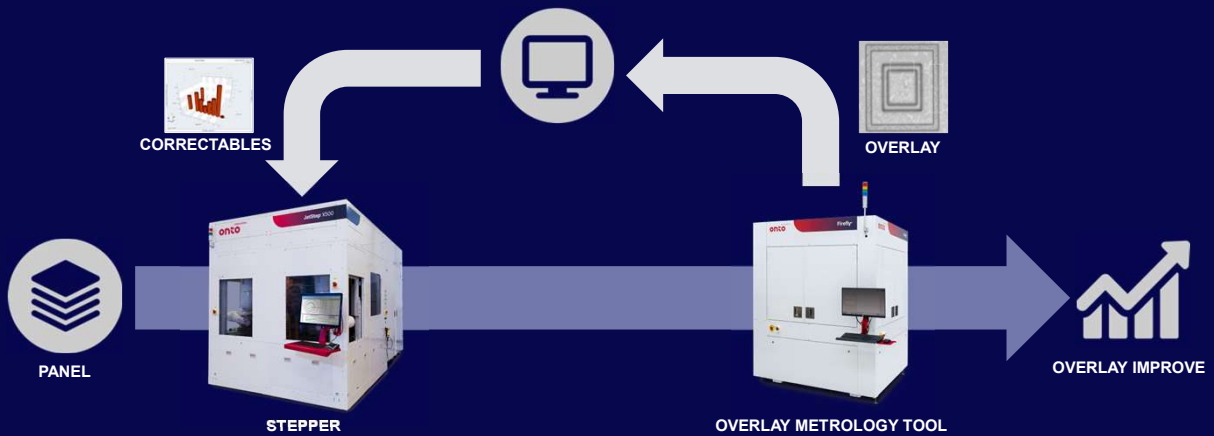
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Overlay Improvement Solution for Organic Substrates (CCL)

Data Feedback Loop



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Overlay Improvement Solution for Organic Substrates (CCL)

New algorithm to optimize on product overlay

Function Verified

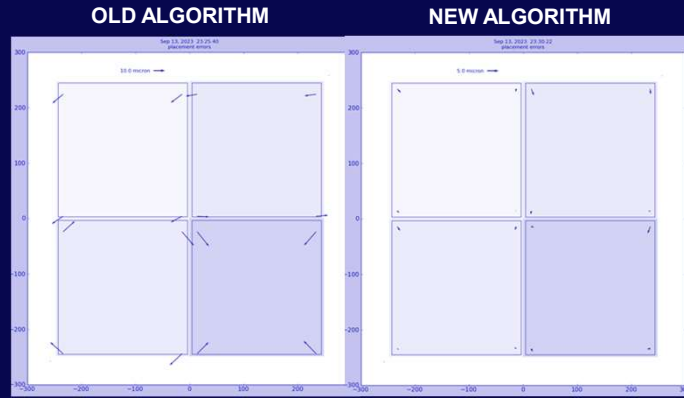
- ✓ Correctable Creation
- ✓ Correctable Loading into Tool
- ✓ Correctable Applied During Exposure

Panel Verified

- ✓ Panel with New Algorithm
- ✓ Panel with Old Algorithm
- ✓ OVL Results Confirmed

Alignment

- ✓ New SW Algorithm
- ✓ Improved Repeatability 60-80%



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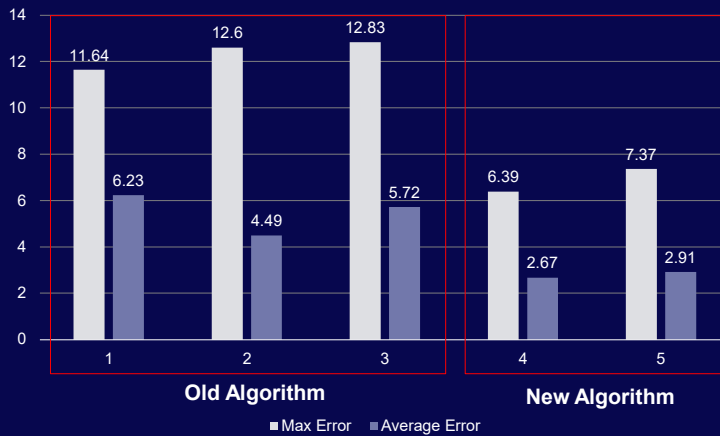


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Organic Substrates – Overlay Improvement

On product overlay

Overlay Results: Old Algorithm vs New Algorithm



Future overlay improvements:

- ❖ Via & RDL patterned by stepper
- ✓ Via defined with hard mask or PID

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Packaging Applications Center of Excellence (PACE)

Leadership through R&D

Vision: Establish Onto as the Innovation Leader in Advanced Packaging


Mission: Accelerate the Advanced Packaging Technology Roadmap by working with customers, material suppliers, and OEMs to create and demonstrate next generation hardware and software solutions for the PLP market




Wilmington, MA

ONTO INNOVATIONS

Panel Lithography
JetStep® X500,
S3500



Process Control
Firefly® G3



Control & Analytics Software




Collaboration for success:

- Organic Substrates (CCL) process flow
- Glass Core process flow
- Adjacent OEMs to develop new solutions
- Supply Chain: substrates, photoresist, PID, build up films, new processes

PACE Support Process Capabilities

Coater/Laminator | Dedicated Stepper | Automated Developer | SEM Cross Section | Overlay & CD Metrology | Film Thickness Measurement | Curing Ovens
Integrated Solutions | Advanced Process Development | Improved Products & Support | Dedicated Apps Lab Staff



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Thank You

谢谢 | 謝謝

ありがとう

Obrigado

Danke

감사합니다

Merci

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www.ontoinnovation.com



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Abstract: *“As the Advanced Packaging substrate interconnect density continues to increase rapidly, driven by next generation HPC, AI and VR/AR applications, there has been a paradigm shift in the package architecture to replace organic substrates with glass core substrates. Typically, organic substrates support HVM RDL structures of 9/12 μm line/space and, in R&D, down to 5/5 μm line/space. Beyond this, the substrate’s dimensional stability and flatness will limit the resolution and overlay performance, impacting customer product roadmaps. Glass core substrates are expected to provide the solution. However, glass core has its own challenges. Onto Innovation understands these challenges, and provides solutions through its lithography, inspection, metrology and SW products. Onto Innovation is working with adjacent OEMs and the material supply chain to provide customers with early access to next generation products through its Packaging Applications Center of Excellence (PACE). This talk will discuss the benefits and challenges of both architectures and explores the possibility of extending the useful life of organic substrates beyond 5/5 μm line/space.*